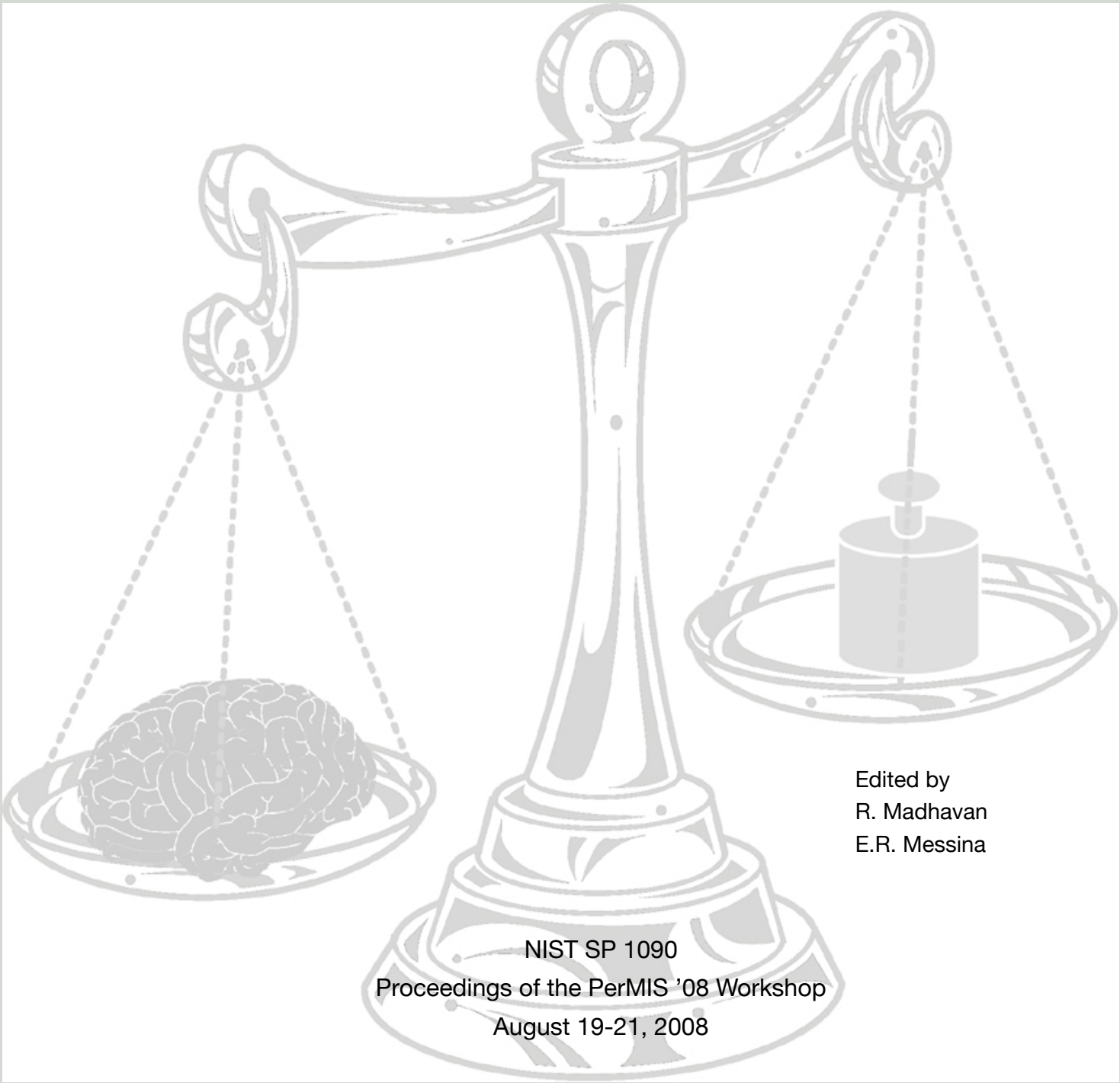
PERFORMANCE METRICS
FOR
INTELLIGENT SYSTEMS (PERMIS) WORKSHOP

National Institute of Standards and Technology, Gaithersburg, Maryland USA
August 19 - 21, 2008



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R. Madhavan
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August 19-21, 2008

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FOREWORD

The 2008 Performance Metrics for Intelligent Systems (PerMIS'08) Workshop is the eighth in the series that started in 2000, targeted at defining measures and methodologies of evaluating performance of intelligent systems. The workshop has proved to be an excellent forum for discussions and partnerships, dissemination of ideas, and future collaborations in an informal setting. Attendees usually include researchers, graduate students, practitioners from industry, academia, and government agencies.

PerMIS'08 aims at *identifying and quantifying contributions of functional intelligence towards achieving success*. Our working definition of functional intelligence is "the ability to act appropriately in an uncertain environment, where appropriate action is that which increases the probability of success", and success is "the achievement of behavioral goals" (J. Albus, 1991). In addition to the main theme, as in previous years, the workshop focuses on applications of performance measures to practical problems in commercial, industrial, homeland security, and military applications. Topic areas include, but are not limited to:

Defining and measuring aspects of a system:

- The level of autonomy
- Human-robot interaction
- Collaboration & coordination
- Taxonomies
- Biologically inspired models

Evaluating components within intelligent system

- Sensing and perception
- Knowledge representation, world models, ontologies
- Planning and control
- Learning and adaption
- Reasoning

Infrastructural support for performance evaluation

- Testbeds and competitions for intercomparisons
- Instrumentation and other measurement tools
- Simulation and modeling support

Technology readiness measures for intelligent systems

Applied performance measures in various domains, e.g.,

- Intelligent transportation systems
- Emergency response robots (search and rescue, bomb disposal)
- Homeland security systems
- De-mining robots
- Defense robotics
- Hazardous environments (e.g., nuclear remediation)
- Industrial and manufacturing systems
- Space/Aerial robotics
- Medical Robotics & assistive devices

PerMIS'08 features five plenary addresses and seven special sessions. The plenary speakers are world-class experts in their own field and we are confident that the attendees will be able to benefit from their presentations. This year, there is a special session for every (parallel) general session. Over the course of three days, there will be twelve sessions related to performance of intelligent systems covering an array of topics from medical systems to manufacturing, mobile robotics to virtual automation, human-system interaction to biologically inspired models, and much more.

Special thanks are due to the Program Committee for publicizing the workshop, the special session organizers for proposing interesting topics and bringing together researchers related to their sessions, and the reviewers who provided feedback to the authors, and helped us to assemble an excellent program. We much appreciate the authors submitting their papers to this workshop and for sharing their thoughts and experiences related to their research with the workshop attendees.

PerMIS'08, is sponsored by NIST with technical co-sponsorship of the IEEE Washington Section Robotics and Automation Society Chapter and in-cooperation with the Association for Computing Machinery (ACM) Special Interest Group on Artificial Intelligence (SIGART). As in previous years, the proceedings of PerMIS will be indexed by INSPEC, Compendex, ACM's Digital Library, and are released as a NIST Special Publication. Springer Publishers was back again this year to raffle off some of the books that were displayed at their booth during the course of the workshop. Selected papers from this workshop are being included in an edited book volume by Springer. We gratefully acknowledge the support of our sponsors.

We sincerely hope that you enjoy the presentations and the social programs!

Raj Madhavan
Program Chair

Elena Messina
General Chair

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PLENARY SPEAKER

Mr. Alan Schultz

Navy Center for Applied Research in Artificial Intelligence (NCARAI), USA

Cognitively Enhanced Intelligent Systems

Tues. 8:30 am

ABSTRACT

We hypothesize that adding computational cognitive reasoning components to intelligent systems will result in three benefits:
Most if not all intelligent systems must interact with humans, who are the ultimate users of these systems. Giving the system cognitive models can enhance the human-system interface by allowing more common ground in the form of cognitively plausible representations and qualitative reasoning. By using cognitive models, reasoning mechanisms and representations, we believe that we can yield a more effective and efficient interface that accommodates the user.

Since the resulting system in interacting with the human, giving it behaviors that are more natural to the human can also result in more natural interactions between the human and the intelligent system. For example, mobile robots that must work collaboratively with humans can actually result in less effective interactions if its behaviors are alien or non-intuitive to the human. By incorporating cognitive models, we can develop systems whose behavior is more expected and natural.

One key interest is in measuring the performance of intelligent systems. We propose that an intelligent system that is cognitively enhanced can be more directly compared to human level performance. Further, if cognitive models of human performance have been developed in creating the intelligent system, we can directly compare the intelligent systems behavior and performance in the task to the human subject behavior and performance.

In this talk, I will present several instantiations of developing cognitively enhanced intelligent systems.

BIOGRAPHY

Alan C. Schultz is the Director of the Navy Center for Applied Research in Artificial Intelligence at the Naval Research Laboratory in Washington, DC. His research is in the areas of human-robot interaction, cognitive robotics, evolutionary robotics, learning in robotic systems, and adaptive systems. He is the recipient of an Alan Berman Research Publication Award, and has published over 90 articles on HRI, machine learning and robotics. Alan is currently the co-chair of the AAAI Symposia Series, and chaired the 1999 and 2000 AAAI Mobil Robot Competition and Exhibitions.

PLENARY SPEAKER

Prof. Allison Okamura

The Johns Hopkins University, USA

Haptics in Medical Robotics: Surgery, Simulation, and Rehabilitation

Tues. 2:00 pm

ABSTRACT

Haptics is the science and technology of experiencing and creating touch sensations. This talk will examine the role of haptics in three types of medical systems: surgical robotics, surgical simulators, and rehabilitation robotics. Robot-assisted surgery can improve the outcomes of medical procedures by enhancing accuracy and minimally invasive access, thereby reducing patient trauma and recovery time. However, the current lack of force and tactile information is hypothesized to compromise system performance. With approaches ranging from psychophysical studies to control systems engineering, we are designing teleoperated robots capable of providing haptic feedback in challenging surgical environments. Haptic information is also needed for accurate surgical simulation. Surgical simulators present a safe and potentially effective method for surgical training, and can also be used in robot-assisted surgery for pre- and intra-operative planning. I will describe experiments to determine the mechanics of interaction between surgical instruments and tissues, as well as techniques for accurate patient-specific modeling. Finally, rehabilitation through robotically enabled orthotics and prosthetics inherently requires understanding and appropriate generation of haptic interactions. Our recent work in this area includes motor control augmentation with an exoskeleton robot, and studies of the role of haptic proprioception in prosthetic limb use.

BIOGRAPHY

Allison M. Okamura received the BS degree from the University of California at Berkeley in 1994, and the MS and PhD degrees from Stanford University in 1996 and 2000, respectively, all in mechanical engineering. She is currently an associate professor of mechanical engineering and the Decker Faculty Scholar at Johns Hopkins University. She is associate director of the Laboratory for Computational Sensing and Robotics and a thrust leader of the NSF Engineering Research Center for Computer-Integrated Surgical Systems and Technology. Her awards include the 2005 IEEE Robotics Automation Society Early Academic Career Award, the 2004 US NSF CAREER Award, the 2004 JHU George E. Owen Teaching Award, and the 2003 JHU Diversity Recognition Award. Her research interests are haptics, teleoperation, medical robotics, virtual environments and simulators, prosthetics, rehabilitation engineering, and engineering education.

PLENARY SPEAKER

Prof. Erwin Prassler

Applied Science Institute, Germany

Incremental Integration, Evaluation, and Harmonization of Components of a Reference Platform for Service Robotics

Wed. 8:30 am

ABSTRACT

In industrial robotics, system integration is a rather common business. Robot manufacturers typically team up with a number of so-called system integrators, which design robot cells, assembly lines and entire manufacturing plants out of “standardized” components, such as manipulators, sensors, tools, and conveyor systems.

In service robotics the situation is in no way comparable. Service robots are typically considered as mass products, which are designed like dish washers or play stations. System integration is simply part of the regular product design.

It would be rather irrelevant to discuss this issue any further, if the design of a service robot for some specific application was a task like the design of a dish washer. As a matter of fact, the two tasks have not much if anything at all in common.

The design of a service robot is more the result of the ingenuity of an engineer rather of established procedures or methodologies or even technologies. Typically every new service robot is design from scratch. Not too seldom, the service task itself and the operational constraints are not too well understood, neither is the business model under which the automation of a service could become an economic success. A plenitude of components such as sensors, actuators, operating systems, algorithms are available but no common recipe for integrating and compiling them into a competitive product.

Service robotics today is in a situation very much comparable to the situation of the car industry in 1885, when Carl Benz built the first car. The industry is virtually not existing. Potential players and investors are skeptical because not only a realistic market but also a realistic technology assessment gives them a rather fuzzy picture.

This situation has motivated the German Ministry for Education and Research to invest into a so-called technology platform for service robotics. Other funding agencies such as the European Commission are implementing similar initiatives.

In my presentation I will talk about the German Service Robotics Initiative, which as a major activity pushes the development of such a technology platform. The platform is considered as a vehicle for understanding and managing the requirements for system integration in service robotics. I will talk about a first approach of this Initiative to incrementally integrate, evaluate and harmonize available off the shelf components and their interfaces to simplify and accelerate the development of new service robots. I will also talk about the lessons learned in this Initiative and how they are currently being picked up in other initiatives to promote the development of harmonized and/or standardized building blocks for service robots.

BIOGRAPHY

Erwin Prassler received a master's degree in Computer Science from the Technical University of Munich in 1985 and a Ph.D. in Computer Science from the University of Ulm in March 1996. For his doctoral dissertation he received the AKI dissertation award in September 1997. Between 1986 and 1989, Dr. Prassler held positions as a member of the scientific staff at the Technical University of Munich and as a guest researcher in the Computer Science Department at the University of Toronto. In fall 1989, he joined the Research Institute for Applied Knowledge Processing (FAW) in Ulm, where he headed a research group working in the field of mobile robots and service robotics between 1994 and 2003. In 1999, Dr. Prassler entered a joint affiliation with Gesellschaft fur Produktionssysteme (GPS) in Stuttgart, where directed the department for Project Management and Technology Transfer. In this function, Dr. Prassler coordinated the MORPHA project (Interaction and Communication between Humans and Intelligent Robot Assistents, www.morpha.de) one of six national research projects in the field of Human Machine Interaction funded by the German Ministry for Education and Research. In March 2004, Dr. Prassler was appointed as an Associate Professor at the Bonn-Aachen International Center for Information Technology. Together with Prof. Rolf Dieter Schraft, director of Fraunhofer IPA in Stuttgart, he is currently co-ordinating the German Service Robotice Initiatve DESIRE (www.service-robotik-initiative.de), a joint national research project involving 7 academic and 6 industrial partners.

PLENARY SPEAKER

Prof. Alonzo Kelly

Carnegie Mellon University, USA

Various Tradeoffs and Metrics of Performance for Field Robots

Wed. 2:00 pm

ABSTRACT

A mature systems engineering discipline is exemplified by aerospace engineering where purpose-built vehicles are designed while regularly consulting system level performance models to help guide the design optimization process. Robotics has not yet identified such rich and universal performance models but useful performance models do arise naturally in the performance of the work. This talk will discuss a large number of field robotic systems in an attempt to identify some system level constraints, tradeoffs and metrics which seem to be valuable in formulating the quest for an optimal system. Examples include the hard constraints of safe real-time replanning, the optimal update rate of a visual servo, the related tradeoff between systematic and random error accumulation in mapping, and the relative completeness of planning search spaces and its affect on winning robot races.

BIOGRAPHY

Dr. Alonzo Kelly is an associate professor at the Robotics Institute of Carnegie Mellon University. He has also worked as a member of the technical staff at MD Robotics, Canada and at NASA's Jet Propulsion Laboratory. His research typically concerns wheeled mobile robots operating in both structured and unstructured environments. His work spans many sub-specialties of mobile robots including control, position estimation, mapping, motion planning, simulation, and human interfaces. It also spans many application areas including outdoor unmanned ground vehicles, agricultural and mining vehicles, planetary rovers, and indoor automated guided vehicles.

PLENARY SPEAKER

Prof. Sunil Kumar Agrawal

University of Delaware, USA

Robotic Exoskeletons for Gait Assistance and Training of the Motor Impaired

Thurs. 8:30 am

ABSTRACT

Robotics is emerging as a promising tool for training of human functional movement. The current research in this area is focused primarily on upper extremity movements. This talk describes novel designs of three lower extremity exoskeletons, intended for gait assistance and training of motor-impaired patients. The design of each of these exoskeletons is novel and different. Force and position sensors on the exoskeleton provide feedback to the user during training. The exoskeletons have undergone tests on healthy and chronic stroke survivors to assess their potential for treadmill training. These results will be presented. GBO is a Gravity Balancing un-motorized Orthosis which can alter the gravity acting at the hip and knee joints during swing. ALEX is an Actively driven Leg Exoskeleton which can modulate the foot trajectory using motors at the joints. SUE is a bilateral Swing-assist Un-motorized Exoskeleton to propel the leg during gait. This research was supported by NIH through a BRP program.

BIOGRAPHY

Prof. Agrawal received a Ph.D. degree in Mechanical Engineering from Stanford University in 1990. He is currently the Director of Mechanical Systems Laboratory. He has published close to 200 journal and conference papers and 2 books in the areas of controlled mechanical systems, dynamic optimization, and robotics. Dr. Agrawal is a Fellow of the ASME and his other honors include a Presidential Faculty Fellowship from the White House in 1994, a Bessel Prize from Germany in 2003, and a Humboldt US Senior Scientist Award in 2007. He has served on editorial boards of numerous journals published by ASME and IEEE.

August 19

TUESDAY

PROGRAM

PERMIS

Note: Please click on the paper title to view it in pdf.

08:15	**Welcome & Overview**
08:30	**Plenary Presentation:** **Alan Schultz** ***Cognitively Enhanced Intelligent Systems***
09:30	**Coffee Break**
10:00	**TUE-AM1 Performance Evaluation** ***Chairs: James Spall & Craig Schlenoff*** • Evolution of the SCORE Framework to Enhance Field-Based Performance Evaluations of Emerging Technologies [Brian Weiss, Craig Schlenoff] • Reliability Estimation and Confidence Regions from Subsystem and Full System Tests via Maximum Likelihood [James Spall] • Fuzzy-Logic-Based Approach for Identifying Objects of Interest in the PRIDE Framework [Zeid Kootbally, Craig Schlenoff, Raj Madhavan, Sebti Foufou] • Identifying Objects in Range Data Based on Similarity Transformation Invariant Shape Signatures [Xiaolan Li, Afzal Godil, Asim Wagan] • Stepfield Pallets: Repeatable Terrain for Evaluating Robot Mobility [Adam Jacoff, Anthony Downs, Ann Virts, Elena Messina] • Potential Scaling Effects for Asynchronous Video in Multirobot Search [Prasanna Velagapudi, Paul Scerri, Katia Sycara, Huadong Wang, Michael Lewis]
12:30	**Lunch**
14:00	**Plenary Presentation:** **Allison Okamura** ***Haptics in Medical Robotics: Surgery, Simulation, and Rehabilitation***
15:00	**Coffee Break**
15:30	**TUE-PM1 Human-System Interaction** ***Chairs: Michael Lewis & Birsen Donmez*** • Evaluation Criteria for Human-Automation Performance Metrics [Birsen Donmez, Patricia Pina, Mary Cummings] • Assessing Measures of Coordination Demand Based on Interaction Durations [Michael Lewis, Jijun Wang] • The Gestural Joystick and the Efficacy of the Path Tortuosity Metric for Human/Robot Interaction [Richard Voyles, Jaewook Bae, Roy Godzdanker] • Modeling of Thoughtful Behavior with Dynamic Expert System [Vadim Stefanuk]
19:00	**Reception**

PERMIS PROGRAM

August 19 TUESDAY

Note: Please click on the paper title to view it in pdf.

08:15	**Welcome & Overview**
08:30	**Plenary Presentation:** **Alan Schultz** ***Cognitively Enhanced Intelligent Systems***
09:30	**Coffee Break**
10:00	**TUE-AM2 Special Session I: Cognitive Systems of EU Cognition Programme** ***Organizer: Patrick Courtney*** • Cognitive Systems of EU Cognition Programme* [Patrick Courtney] • The Rat's Life Benchmark: Competing Cognitive Robots [Olivier Michel, Fabien Rohrer] • The iCub Humanoid Robot: An Open Platform for Research in Embodied Cognition [Giorgio Metta, Giulio Sandini, David Vernon, Lorenzo Natale, Francesco Nori] • An Open-Source Simulator for Cognitive Robotics Research: The Prototype of the iCub Humanoid Robot Simulator [Vadim Tikhanoff, Angelo Cangelosi, Paul Fitzpatrick, Giorgio Metta, Lorenzo Natale, Francesco Nori] • Symbiotic Robot Organisms: REPLICATOR and SYMBRION Projects [Serge Kernbach, Eugen Meister, Florian Schlachter, Kristof Jebens, Marc Szymanski, Jens Liedke, Davide Laneri, Lutz Winkler, Thomas Schmickl, Ronald Thenius, Paolo Corradi, Leonardo Ricotti] • Virtual Agent Modeling in the RASCALLI Platform [Christian Eis, Marcin Skowron, Brigitte Krenn]
12:30	**Lunch**
14:00	**Plenary Presentation:** **Allison Okamura** ***Haptics in Medical Robotics: Surgery, Simulation, and Rehabilitation***
15:00	**Coffee Break**
15:30	**TUE-PM2 Special Session II: Architectures for Unmanned Systems** ***Organizers: Roger Bostelman & James Albus*** • UAV Architectures* [George Vachtsevanos] • Architectures for Unmanned Systems* [James Albus] • Levels-of-Autonomy of the ASTM F41 Unmanned Maritime Vehicles Standard* [Mark Rothgeb] • Ontological Perspectives for Autonomy Performance [Hui-Min Huang, Elena Messina, Tsai Hong, Craig Schlenoff]
19:00	**Reception**

*Presentation Only

August

PROGRAM

PERMIS

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WEDNESDAY

Note: Please click on the paper title to view it in pdf.

08:15	Overview
08:30	**Plenary Presentation:** **Erwin Prassler** ***Incremental Integration, Evaluation, and Harmonization of Components of a Reference Platform for Service Robotics***
09:30	Coffee Break
10:00	**WED-AM1 Metrics & Measures** ***Chairs: Scott Spetka & Robert Wade*** • Robotic Systems Technical and Operational Metrics Correlation [Jason Schenk, Robert Wade] • Survey of Domain-Specific Performance Measures in Assistive Robotic Technology [Katherine Tsui, Holly Yanco, David Feil-Seifer, Maja Mataric] • Refining the Cognitive Decathlon [Robert Simpson, Charles Twardy] • Using Metrics to Optimize a High Performance Intelligent Image Processing Code [Scott Spetka, Susan Emeny, George Ramseyer, Richard Linderman] • Measurement Techniques for Multiagent Systems [Robert Lass, Evan Sultanik, William Regli] • RoboCupRescue Robot League: 2008 Overview* [Adam Jacoff, Andreas Birk, Johannes Pellenz, Ehsan Mihankhah, Raymond Sheh, Satoshi Tadokoro]
12:30	Lunch
14:00	**Plenary Presentation:** **Alonzo Kelly** ***Various Tradeoffs and Metrics of Performance for Field Robots***
15:00	Coffee Break
15:30	**WED-PM1 Autonomous Systems** ***Chairs: James Gunderson & Edward Tunstel*** • Integrating Reification and Ontologies for Mobile Autonomous Robots [James Gunderson, Louise Gunderson] • Quantification of Line Tracking Solutions for Automotive Applications [Jane Shi, Rick Rourke, Dave Groll, Peter Tavora] • Mobile Robotic Surveying Performance for Planetary Surface Site Characterization [Edward Tunstel] • Evaluating Situation Awareness of Autonomous Systems [Jan Gehrke]
18:30	Banquet

*Presentation Only

Note: Please click on the paper title to view it in pdf.

08:15	**Overview**
08:30	**Plenary Presentation:** **Erwin Prassler** ***Incremental Integration, Evaluation, and Harmonization of Components of a Reference Platform for Service Robotics***
09:30	**Coffee Break**
10:00	**WED-AM2 Special Session III: Performance Metrics for Perception in Intelligent Manufacturing** ***Organizers: Tsai Hong & Roger Eastman*** • Performance of Super-Resolution Enhancement for Flash LADAR Data [Shuowen Hu, Susan Young, Tsai Hong] • Performance Evaluation of Laser Trackers [Bala Muralikrishnan, Daniel Sawyer, Christopher Blackburn, Steven Phillips, Bruce Borchardt, Tyler Estler] • Preliminary Analysis of Conveyor Dynamic Motion for Automation Applications [Jane Shi] • 3D Part Identification Based on Local Shape Descriptors [Xiaolan Li, Afzal Godil, Asim Wagan] • Calibration of a System of a Gray-Value Camera and an MDSI Range camera [Tobias Hanning, Aless Lasaruk] • Dynamic 6DOF Metrology for Evaluating a Visual Servoing System [Tommy Chang, Tsai Hong, Mike Shneier, German Holguin, Johnny Park, Roger Eastman]
12:30	**Lunch**
14:00	**Plenary Presentation:** **Alonzo Kelly** ***Various Tradeoffs and Metrics of Performance for Field Robots***
15:00	**Coffee Break**
15:30	**WED-PM2 Special Session IV: Results from a Virtual Manufacturing Automation Competition** ***Organizers: Stephen Balakirsky, Raj Madhavan & Chris Scrapper*** • NIST/IEEE Virtual Manufacturing and Automation Competition: From Earliest Beginnings to Future Directions [Stephen Balakirsky, Raj Madhavan, Chris Scrapper] • Analysis of a Novel Docking Technique for Autonomous Robots [George Henson, Michael Maynard, Xinlian Liu, George Dimitoglou] • Partitioning Algorithm for Path Determination of Automated Robotic Part Delivery System in Manufacturing Environments [Payam Matin, Ali Eydgahi, Ranjith Chowdary] • Algorithms and Performance Analysis for Path Navigation of Ackerman-Steered Autonomous Robots [George Henson, Michael Maynard, George Dimitoglou, Xinlian Liu]
18:30	**Banquet**

Note: Please click on the paper title to view it in pdf.

08:15	Overview
08:30	**Plenary Presentation:** **Sunil Kumar Agrawal** ***Robotic Exoskeletons for Gait Assistance and Training of the Motor Impaired***
09:30	Coffee Break
10:00	**THU-AM1 Model-based Performance Assessment** ***Chairs: Kate Remley & Kam Saidi*** • Wireless Communications in Tunnels for Urban Search and Rescue Robots [Kate Remley, George Hough, Galen Koepke, Dennis Camell, Robert Johnk, Chriss Grosvenor] • A Performance Assessment of Calibrated Camera Networks for Construction Site Monitoring [Itai Katz, Nicholas Scott, Kam Saidi] • A Queuing-Theoretic Framework for Modeling and Analysis of Mobility in WSNs [Harsh Bhatia, Rathinasamy Lenin, Aarti Munjal, Srini Ramaswamy, Sanjay Srivastava] • Towards Information Networks to Support Composable Manufacturing [Mahesh Mani, Albert Jones, Junho Shin, Ram Sriram] • 3D Reconstruction of Rough Terrain for USARSim using a Height-map Method [Gael Roberts, Stephen Balakirsky, Sebti Foufou]
12:30	Lunch
14:00	**THU-PM1 Special Session VI: Biologically Inspired Models of Intelligent Systems** ***Organizer: Gary Berg-Cross*** • Introduction to Biological Inspiration for Intelligent Systems [Gary Berg-Cross] • Overview of Biologically Inspired Cognitive Architectures (BICA)* [Alexei Samsonovich] • Recent modeling and Rapid Prototyping Experience Aimed at Building Architectures of Cognitive Agents* [Giorgio Ascoli] • Applying Developmental-Inspired Principles to the Field of Developmental Robotics [Gary Berg-Cross] • Discussion of Biologically Inspired Models [Panel]
16:00	Coffee Break
16:30	Adjourn

*Presentation Only

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08:15	**Overview**
08:30	**Plenary Presentation:** **Sunil Kumar Agrawal** ***Robotic Exoskeletons for Gait Assistance and Training of the Motor Impaired***
09:30	**Coffee Break**
10:00	**THU-AM2 Special Session V: Quantitative Assessment of Robot-generated Maps** ***Organizers: Chris Scrapper, Raj Madhavan & Stephen Balakirsky*** • Characterizing Robot-Generated Maps: The Importance of Representations and Objective Metrics* [Chris Scrapper, Raj Madhavan, Stephen Balakirsky] • Using Virtual Scans to Improve Alignment Performance in Robot Mapping [Rolf Lakeamper, Nagesh Adluru] • The Role of Bayesian Bounds in Comparing SLAM Algorithms Performance [Andrea Censi] • Map Quality Assessment [Asim Wagan, Afzal Godil, Xiaolan Li] • Discussion: Roadmap for Map Evaluation Frameworks
12:30	**Lunch**
14:00	**THU-PM2 Special Session VII: Medical Robotics** ***Organizer: Ram Sriram*** • Overcoming Barriers to Wider Adoption of Mobile Telerobotic Surgery: Engineering, Clinical and Business Challenges [Gerald Moses, Charles Doarn, Blake Hannaford, Jacob Rosen] • Calibration of a Computer Assisted Orthopaedic Hip Surgery Phantom [Daniel Sawyer, Nick Dagalakis, Craig Shakarji, Yong Kim] • HLPR Chair – A Novel Patient Transfer Device [Roger Bostelman, James Albus, Joshua Johnson] • Robotic Navigation in Crowded Environments: Key Challenges for Autonomous Navigation Systems [James Ballantyne, Salman Valibeik, Ara Darzi, Guang-Zhong Yang]
16:00	**Coffee Break**
16:30	**Adjourn**

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